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Published in:
ICCE 2010

Publication date:
2010

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Sumer, B. M., Sen, M. B., Karagali, I., Ceren, B., Fredsøe, J., Sottile, M., Zilioli, L., & Fuhrman, D. R. (2010). Flow and Sediment transport under a plunging solitary wave. In *ICCE 2010: Book of abstracts* (pp. 285). American Society of Civil Engineers.

Paper No. 285

FLOW AND SEDIMENT TRANSPORT UNDER A PLUNGING SOLITARY WAVE

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INTRODUCTION

A solitary wave offers a simple, isolated experimental environment to study the flow and sediment transport induced by a breaking wave. (Recall, however, that wave-setup is nonexistent in solitary waves.) The purpose of the present investigation is to gain an understanding of the entire sequence of wave breaking (shoaling, wave breaking, runup, rundown, hydraulic jump, and trailing waves), and the resulting sediment transport, by measuring the bed shear stress, and the pore-water pressure synchronized with flow visualization of the breaking process.

EXPERIMENTS

Two kinds of experiments were carried out: Rigid-bed experiments and sediment-bed experiments, carried out in two wave flumes (with dimensions 28 m x 0.80 m x 0.60 m, and 28 m x 1 m x 4.0 m, respectively). Solitary waves were produced by a piston type wave generator. The beach (with a slope of 1:14) was made of PVC plates in the rigid-bed experiments. Bed shear stress was measured synchronized with the surface elevation at eight sections over the beach. A Dantec 55R46 hot-film probe, mounted flush to the bottom PVC plate, was used to measure the bed shear stress. The dimensions of the hot film sensor were ($d_x \times d_z$) = (0.2 mm$\times$0.75 mm) in which *x* is the direction of the wave propagation, and *z* the transverse direction. As the hot film sensor does not sense the direction of the bed shear stress, synchronized velocity measurements were made at y = 0.4 mm (y being the vertical distance from the bed) just above the hot-film probe, in order to monitor the direction of the bed shear stress, using a Laser Doppler Anemometer (LDA) equipment. Synchronized flow visualizations were also performed, using a digital video recorder. With this, the observed features of the breaking process were related to the measured bed shear stress. In the sediment-bed experiments, the beach (with exactly the same slope as in the rigid-bed experiments) was formed with sand, with d_{50} = 0.18 mm and the geometric standard deviation $\sigma_g(=\sqrt{d_{84}/d_{16}})=1.6$. Synchronized pore-water pressure measurements (using Honeywell RS395 pressure transducers) and surface elevation measurements were made, and the bed profiles were measured. The pore-water pressure was measured at five depths, y = 0, -3.5, -6.5, -11.5 and -16.5 cm from the bed surface, in the middle of the flume, at each section. The bed profile was measured in the middle of the flume, using a point gage. In order to obtain a better accuracy in the measurement, the bed was subjected to four successive waves (rather than one single wave) in four separate tests, and the cumulative effect of the latter was eventually measured as the bed profile.

RESULTS

Fig. 1 gives an example whereby the mean and the standard deviation of the maximum value of the bed shear stress (in terms of the friction velocity) are plotted versus the distance from the toe of the beach. The sample size in the calculations of these statistics was 40. The non-zero r.m.s. value for small values of the distance from the toe in the shoaling area is due to the non-laminar flow regime of the solitary wave boundary layer (Vittori and Blondeaux, 2008, and Sumer et al., 2010). The figure shows that, with the wave breaking, the mean and the standard deviation (turbulence) experience a tremendous increase. The pore pressure measurements show the presence of upward-directed pressure gradient at the surface of the bed during the rundown stage (which also includes a hydraulic jump), meaning that the sediment grains at the surface of the bed is subject to an additional lift force during this stage, which in effect "amplifies" the Shields parameter. The measured bed profile is interpreted in terms of the bed shear stress and the pore-water pressure measurements.

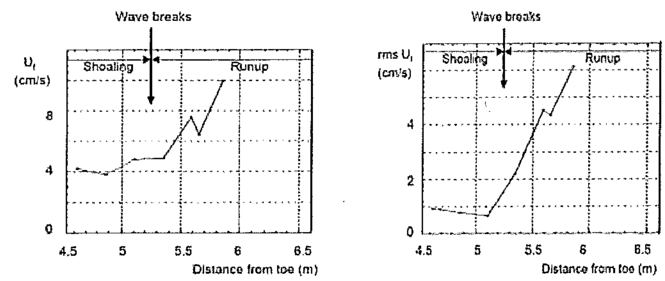

Figure 1 - Maximum value of the mean (Left) and standard deviation (Right) of friction velocity, during shoaling and runup, plotted against the distance from the toe of the beach.

REFERENCES

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